CORRELATION OF SUBJECTS IN SECONDARY MATHEMATICAL TEACHING.[1]

IT is no longer possible for the teacher of secondary mathematics to define his function in terms of subject-matter merely. So long as the function of the school was conceived to be the purveying of intellectual material to a class of selected individuals, the fallacy of such a definition was not readily discernible. But in these latter days, instead of defining the teacher as one *licensed* to teach, we prefer to define him as one who *can* teach. This change in the definition of a teacher alters the conception of his teaching function. The change in the definition also shifts the emphasis of attention in the teaching process from the subject to the person taught, and many improvements have followed in the train of this transfer of emphasis. It is here maintained, and it could be readily proved, that of all teachers, mathematical teachers have shown about the least disposition to respond to the pedagogical advance of recent times. Many of us seem to think that, like whisky, truth, and violins, mathematical matter and method undergo a ripening process with the flight of years when kept in a perfectly dry condition, and that Euclid is about the best after all.

It is, however, encouraging to remember that, while there may be persons here who can recall when the secondary mathematical teacher's office was regarded as definable in purely intellectual terms, it is also true that such persons have lived long enough to see a significant breaking away from the narrow ideals of a past age. The introduction into nearly all branches and grades of school work of a wonderfully vitalizing democratic impulse has already been wrought. One of the significant consequences of this new impulse is that no thinker on modern educational problems now attempts to define teaching of any sort, unless perchance it be mathematical teaching, without calling to

[1] Read at the autumn conference of the Affiliated and Co-operating Schools of the University of Chicago, 1902.

his aid the ideas which lie back of the words "pupil" and "society." If there now remains any subject of the curriculum whose devotees still argue its right to an important place in education, on the score of its general uselessness, it is mathematics. If this is true of mathematics, in one respect at least, mathematics enjoys an unenviable distinction. Notice that it is not maintained that the best mathematicians do actually insist that the reason for the educational importance of their subject is its general worthlessness; but rather that the devotees of other subjects do not hesitate to admit that the chief claim of their subjects for a place in the education of youth is the general usefulness of their teachings. But the art-for-art's-sake, food-for-food's-sake period has not yet passed for mathematics. The doctrine now generally admitted throughout the elementary school, that it is the pupil, rather than the subject, that is to be taught has penetrated secondary mathematical teaching practice to but a very limited extent, while most university teaching remains practically immune from the contagion of this very wholesome doctrine. This last remark will be regarded as gratuitous in this connection unless it be borne in mind that, coming as secondary teachers do from the universities, where they have been lumped with every form of mathematical student regardless of purpose, and looking as they do to universities for educational guidance, these teachers become in great degree imitative of their masters and, wittingly or unwittingly, carry into the secondary school the *en masse* system of handling their pupils.

These strictures on secondary mathematical teaching may seem a little severe; but, brethren of the mathematical fraternity, it is less painful to have the error of our ways pointed out by one another than it is to have them held up to scorn by those who are outside of the order. The question I beg to have you consider is not so much whether the statements of this paper are palatable, as whether they are justifiable under the circumstances.

There is probably no subject in which, as regards subject-matter, there is so little to be taken on faith, authority, or on

any ground other than reason as in mathematics. It is not too much to expect of the specialist in any subject that he shall exemplify in his thought-processes the distinguishing characteristic of his chosen subject. And yet we behold the rather startling spectacle of mathematical teachers being more firmly bound for methods of teaching their subjects to tradition, to authority, and to custom than is the case with almost any other class of teachers. It would even seem that we should ourselves detect this inconsistency. For is it not a part of the common routine of the mathematical teacher to insist during the day that his pupils shall accept nothing as true unless its right to acceptance has been demonstrated on the basis of sufficient reasons, and to spend his evening hours learning what to do next day by what somebody said or did from a hundred to two thousand years ago? Well may our friends, the enemy, deride us with the "Physician, heal thyself!"

A few remarks with regard to another point to which the attention of live teachers should be directed is the notion which is quite prevalent among certain classes of mathematical teachers and which is utterly without foundation that mathematical teachers need no special professional training for their work. If this were true of mathematical teaching, it would be the sole occupation, known to man, which even approaches the professional state, of which it is true. But mathematics sits upon an eminence of lonely grandeur with regard to so many things pedagogical that the mere singularity of her situation has long since ceased to be a matter of surprise to us. With regard to other subjects commonly classed as belonging to, or even aspiring to, the professional state, a confession that no peculiarly professional training is necessary before the novice enters upon its practice is looked upon as relegating it to a primitive state; a study of the situation will also emphasize the "primitive state" view of mathematical teaching. The fact is that when we examine into the question a little we find that almost no mathematical teachers have had special preparation for their work other than that obtained by practicing upon the unfortunates who happened to fall under their tutelage in an

early stage of their teaching experience. In good degree at least this accounts for the oft-repeated maxim among mathematicians that a thorough knowledge of subject-matter is all that is needed to guarantee a successful teaching experience to the prospective mathematical aspirant. Disregarding the unfortunate fact that the advice embodied in these ill-considered words is responsible for very much of the poor mathematical teaching which afflicts the secondary school, the practice of the very persons who utter these words has turned hundreds of students away from a study of the subject to other and more promising fields of endeavor.

But it would perhaps have been safe to assume that persons interested enough in a way of teaching mathematics to attend a discussion on the topic of this occasion are more open-minded to methods of teaching mathematics than are either the class of teachers who believe current mathematical teaching is good enough, or the class who believe the mathematical teacher is born, not made. Many of us have been in direct contact with mathematical teaching long enough to learn, among other things, that secondary mathematical teaching is just about the poorest secondary teaching there is, notwithstanding the fact that we have had something to do with it; and also that the poorest of poor mathematical teachers is likely to be the one who imagines himself to be the born teacher. But some one has well said the really born teacher never knows it. To such persons as are here, however, it will be worth while to say something with reference to correlation in secondary teaching.

The writer has learned from divers sources that his idea of correlation is essentially different from that of many persons. In the minds of many, correlation of subjects means the same thing as the inter-relation of subjects. In my mind inter-relation is not the whole story—nor indeed is it a very large part of it. Interconnection of subjects keeps the thought on subject-matter. Correlation of subjects makes prominent the reaction of the learning mind upon the subjects. Correlation takes place in the mind of the learner; inter-relation is an external thing, brought about by the teacher. In correlation the student is the chief

matter of concern; in inter-relation the student is a secondary consideration. If there is no real bond between the subjects, clearly perceived and vigorously grasped by the learning mind, there is no correlation no matter how perfect the inter-connections of subjects may seem to the teacher. In short, to the writer, correlation means about this: in the natural unfolding of the thought life of the pupil put about him an atmosphere of such subjects as are most conducive to the promotion of this unfolding process, regardless of how the text-book makers have labeled the subjects, or whether they have labeled them at all or not. Correlation makes the education of the pupil—his mathematical education included—emerge from a rational study by the pupil of his own experiences.

For mathematics in the secondary school this would mean, not merely that algebra, geometry, physics, astronomy should be carried along abreast. It means more than this; it means also the laboratory method applied to mathematics. But again it means more; it means that, in connection with the pupil's other scientific work, geometrical surveying with the plane table, the elements of common surveying with the customary instruments, if the school can afford them, with extemporized instruments if it cannot, observational astronomy; also with home-made apparatus, if nothing better is available; scale drawing, graph drawing, the use of squared paper, trigonometry, the elements of the differential calculus—these and more than these should all find a place somewhere in the secondary mathematical training of the pupil. It is not to be understood that these subjects, as separate and more or less complete subjects, should be introduced into the already over-full curriculum; but rather that as the ideas arise in science study of whatever sort, or elsewhere, when a grasp of the quantitative elements is essential to an adequate comprehension on the pupil's part, that whatever mathematical ideas are involved in any natural problem, these ideas shall be systematically brought out, cleared up by graphical work, or otherwise, and fully evaluated mathematically.

It is sometimes objected to the proposed plan here suggested that everything which correlation seeks to accomplish may be

secured more economically by having the mathematical teacher draw his own illustrations from physics, or elsewhere, when he needs them. This objection is valid only when a knowledge of geometry is regarded as getting over 150 pages of a book in a specified time, and time alone is the element to be economized. But a writer of note on education has told us that education is the profitable *losing* of time. Furthermore, when the pupil feels that the problem in question has not been trumped up by the teacher merely to trip him into a little extra study of an inherently uninteresting subject, but that it is a real problem, he takes it up with a spirit and zest unheard-of in the class-room of the mathematical logic-chopper; for occasional illustrations, brought in here and there, to give a pupil temporary contact with what he is supposed to be thinking about always impress the pupil with the feeling that it is after all but an oil and water mixture of two essentially different subjects.

Only those who have tried putting the pupil in the midst of the actual conditions of everyday life can appreciate to the full the influence of normal conditions upon the mental tenor of the pupil. Most of us have been saying so long that the school is an artificial contrivance to produce an enlightened citizenship that we come to think the mechanical is a necessary element in education. These things we say constitute education, forgetful, apparently, that most of the pupil's real education is gotten outside of the school. We imagine we are not teaching when we are interpreting to the pupil, or putting him where he can interpret for himself, the interrogatories which nature confronts him with at every turn. Others tell us we are not teaching when we are doing this and then we are convinced of the error of our way and fall back into the beaten path. Through the stifling effect of our own school experience we have learned how not to be interested in the common phenomena about us and we naturally infer that these matters are of no interest to the high-school boy or girl. One of the strongest arguments for correlation in secondary teaching is that it gets hold of the pupil early enough to keep alive his native interest in common things and teaches the pupil how to make himself at home in

his environment. In course of time he learns the secret of making this environment his tool rather than his master.

Correlation accomplishes much in the way of closing up the gaps for the pupil in our educational system. It breaks down the wooden notion that each subject shall be completed before another is taken up and makes the keynote of educational effort the continuous exercise of all the mental faculties through their normal activities. It plants the pupil firmly upon the solid ground of reality until he has laid by a rich store of well-understood concrete particulars, from which in due time he can proceed with steady step to a higher and surer power of abstraction than can be secured by the insistence on premature accuracy so characteristic of present secondary mathematical teaching. The pupil must see the reason for accuracy and for abstract work before he can profit by them, and this is what correlation, rightly understood and sanely practiced, will do for him; for it accepts the existing mental state of the pupil and demands that the teacher shall meet him more than half-way — all the way, if need be — with both subject-matter and method. It cheapens the teacher's criticisms of the pupils previous training and premiums the teacher's duty as his pupil's helper.

Perhaps the most valuable aid to mathematical teaching in the secondary school rendered by correlation is that it compels the mathematical subjects to break down the bars of that splendid isolation which has hitherto remained proof against argument, reason, and both common and uncommon sense. It gives to mathematics a social value and enables the teacher to state the meaning of his effort in terms of the all-around education of the pupil. This has already been accomplished for most of the other subjects of the secondary school and has been found to put a new significance into them. When this has been accomplished for mathematics, we shall be able to state the educational value of mathematical study in terms less general than mental discipline. This is a consummation devoutly to be wished, for it will be a distinct gain for secondary mathematics. There are many good thinkers among us that dispute the claims of mathematics to so large a place as it now occupies

in the secondary school on grounds of mental discipline alone. Mathematical teachers cannot hold themselves aloof from these disputes. If they are unjustifiable, they must be shown to be so, and even this has not yet been done. Moreover, if the spirit of the present time is any justification of a prediction for the future, we may be pretty sure that the school is to be raised more and more fully to the dignity of a social center as time goes on. The much-vaunted conservatism of mathematical teachers which seems to withstand pretty much everything that can be brought against it cannot hold out successfully against the accusation that in the midst of general educational progress, these teachers alone remain open to the charge of unprogressiveness. Conservatism is all very well under circumstances, but open-mindedness to progress is a virtue at all times. Mathematical teachers, secondary teachers among others, have not always shown themselves possessed of this cardinal pedagogic virtue. We shall be reminded soon of the unpleasant fact that conservatism is a respectable cloak for a tremendous amount of ignorance unless it is judiciously worn. Conservatism can be carried to a degree which amounts to obstruction and approaches dangerously near to the reactionary. There is more than one sincere student of the educational tendencies of our time who believe that most mathematical teachers have reached this stage.

There is an *a priori* reason why mathematical teachers are especially liable to neglect the educational bearings of their teachings and the pedagogical aspects of their subjects. There is no class of subjects which demand such a degree of thorough mental concentration upon subject-matter as do the mathematical subjects. Once the mathematical student, by this intense exclusion of all outside notions, begins to lay hold on the rhythm, symmetry, balance, and proportion of parts in a quantitative question, love for which are the essence of the mathematical turn of mind, and he is in great danger of being led out of sympathetic contact with the struggling pupil whose uncertain grasp of the real meaning of quantitative relations makes impossible for him more than a very feeble and halting enthusiasm for mathematical

truth. Disgusted at the failure of his pupil to appreciate the charm of these truths, which to his trained mind constitute the essence of the beautiful, the enthusiastic mathematical teacher loses interest in his pupil, comes to hold him in a sort of ill-concealed contempt, and at best, from a sense of his duty as teacher, assumes toward the pupil a patronizing air. This, I say, is a natural, though not a necessary, tendency of the real student of mathematics, and no one but the real mathematical student is fit to be a teacher of mathematics. Enthusiasm in the pupil, which again we mathematical folk estimate at altogether too low a rating, can be begotten of nothing save a genuine enthusiasm in the teacher.

No one will make the mistake of assuming the implication of these remarks to be that the teacher of mathematics must remain ignorant of his subject to preserve an interest in his pupil. Quite the contrary implication is intended. It is contended only that mathematical study is subject in an especial sense to the danger of a loss of sympathy on the part of the teacher for the learner. And this is pointed out only with a view to the suggestion that we ought to resist this tendency in the future more successfully than we have hitherto succeeded in resisting it. We must not forget that we are to be teachers primarily, recitation-posts, and mathematical wonders only secondarily, if at all. We must strive to teach in reality, not merely to fling great quantities of mathematical information to the winds, trusting to Providence or luck for some one to happen along to get informed. This process is wasteful of the energies of pupil, teacher, patron, and of every other agency involved in the school, either directly or indirectly. Correlation of subjects keeps the mathematical teacher ever in the same state of mind as his pupil, for both of them are continually engaged in the work of discovering the abstract in the concrete and the concrete in the abstract. This insures a community of interests and sympathies between them.

But the final question remains: Can we prepare our pupils for the university and college by such a plan of teaching? To this it is unfortunate that we must answer, No! if these institutions continue to demand in substance so many pages of certain texts

on geometry or algebra for admission. It is, however, no censure against secondary teaching that it does not fit its students for such an artificial test as this. The charge lies against other defendants. But there is a doctrine which is rapidly gaining the assent of educators to the effect that secondary schools should do the best thing possible for the pupil, and that the universities must be content to select their students from such pupils. Even now the only barrier is the artificial one of the entrance examination in mathematics, and perhaps Latin, for students prepared under correlated teaching make the best quality of university student. Indeed, this is the very reason why the method, if method it may be called, of such teaching is so urgently advocated. That it would bring two students to the mathematical work of the universities where there is now but one, and that every such student would lay a much more vital hold on mathematical truth, are only two of the incidental benefits the general adoption of this plan of secondary mathematical teaching would bring about. Everyone would find himself not only possessed of the mathematical faculty, but he would also learn the secret of getting hold of and using this faculty, which is now generally looked upon as a special gift of the gods vouchsafed to but a favored few.

That the method advocated in this paper would make the work of the teacher lighter is not claimed. It would certainly make selection of efficient teachers a matter of supreme importance. The weakling would certainly bungle; but must we take our bearings from the bungler? There is some encouragement in the thought that even the bungler, by this method, could not produce more unsatisfactory results than current practice is producing. There is also solace in the thought that if the teacher's labor is increased, the dignity of his office would be correspondingly heightened. The teacher by this method would have to stand on his merits, but capable teachers have never hesitated to do this.

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